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changes in the individual, in other words, that the definite current of variation is guided by the inheritance of individual reactions and not by some other principle.

Another consideration is, that individual Variation may play a far less conspicuous rôle than we have assigned to it; in other words, that many of the most important changes in successive generations are so gradual as to be entirely inconspicuous in a single generation.

Our conception of the mechanism or physical basis of Heredity is also to be made much clearer by a series of experiments directed to palingenic variation, in order to ascertain how far the revival of an ancient environment arouses latent hereditary forces. The experiments already well advanced by Cunningham, Agassiz, and Poulton indicate that *progressive inheritance is rather a process of substitution of certain characters and potentialities than the actual elimination implied by Weismann.*

My last word is, that we are entering the threshold of the Evolution problem, instead of standing within the portals. The hardest tasks lie before us, not behind us, and their solution will carry us well into the twentieth century.

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ON THE PRESENCE OF FLUORINE AS A TEST FOR THE FOSSILIZATION OF ANIMAL BONES.

By Dr. Thomas Wilson.

(*Continued from page 317, Vol. XXIX.*)

It is interesting to examine closely this question, and, for that purpose, critical analyses have been made of a large number of bones of different geological ages. The fluorine and phosphoric acid have been determined with exactitude and the proportion of the quantity of fluorine found in the bones to that which apatite, having an equal quantity of phosphorus would contain, has been calculated. The calculation of the fluorine of apatite is easily made by multiplying the weight of the phosphoric acid by the co-efficient 0.0892 which expresses the normal proportion $\frac{2Fl}{3P_2O_5}$

The following series of analyses of bones are arranged in chronological order of the geological formations to which they belong, commencing with the more recent deposits and descending step by step to the most ancient. (The French nomenclature is employed.)

Analyses of bones of fossil animals from various Geologic Epochs or Periods.

Quaternary.	Organic matter.	Ash				Ratio.
		Oxide of iron.	Phosphoric acid.	Fluorine.	Fluorine of apatite.	
1. Rib of a Reindeer from Montreuil (Seine), orange color passing to a bluish green by calcination. *Gain* or *increase* of carbonate of lime, slightly of chlorine, none of silica	16,40	1,45	36,95	1,07	3,30	0,32
2. Horn of Reindeer from the same place, orange-yellowish, reddened by ignition. Gain or increase of carbonate of lime, slight chlorine and silica	19,60	4,35	37,35	0,78	3,33	0,23
3. Tooth of Mammoth (*Elephas primigenius*) from the gray diluvium of Grenelle (Seine). White, slightly yellowish. An abundance of carbonate of lime	....	....	30,60	1,16	2,73	0,42
4. Vertebra of an Ox from Cindre (Allier). Yellowish white becoming bluish by calcination	17,9	0,71	37,19	0,83	2,32	0,25
5. Rib of a *Glyptodon* from the Pampas of Buenos Ayres (Argentine Republic), of average density; yellowish before and after calcination. *Increase* of carbonate of lime, chlorine in normal quantity with little silica	22,60	....	27,38	1,77	2,44	0,73
6. Shell of *Glyptodon* from same locality and with same characteristics	14,90	....	28,41	1,55	2,53	0,61
7. Mylodon, *Os dermiques d'edente*—bones of the skin or shell with tooth-like edges, from the same locality; gray-yellow, becoming gray-green by calcination. Increase of carbonate of lime, traces of chlorine, no silica	13,14	0,95	36,32	1,43	3,24	0,44
8. Rhinoceros teeth from the Cave of Grimaldi, Italy. These were in a good state. The dentine (a) which separates easily from the enamel, was fragile, white, slightly yellow, with a gain of carbonate of lime	10,72	0,40	36,95	1,32	3,30	0,40
The ivory (b) was entirely white and conserved its compactness and hardness—does not appear to have been modified in its texture nor primitive composition	5,32	....	40,34	0,50	3,60	0,14
9. Lamantin (Manatee or Sea Cow). Bones from the peat beds of Scania, Sweden. Light, very porous, black-brown passing to dark-brown by calcination	33,40	5,10	35,77	0,44	3,19	0,14
10. Man, pelvic bone from *l'Abri-sous-Roche* of Cro-Magnon (Dordogne). Light, porous, reddish in color, becoming gray-white by calcination. A gain of carbonate of line, traces of chlorine, no silica	27,50	1,80	34.48	0,52	3,08	0,17

By grouping the results of the determinations of phosphoric acid and of fluorine, the average for the ten specimens from the Quaternary Period is established.

Phosphoric acid, ...	34.14	
Fluorine, ...	1.09	Ratio, 0.36.
Fluorine calculated for apatite, . .	3.04	

Pliocene.	Organic matter.	Ash				Ratio.
		Oxide of iron.	Phosphoric acid.	Fluorine.	Fluorine of apatite.	
1. *Halitherium.* Bone from the deposit of Gourbesville (Manche). Dense, color blackish, becoming gray by calcination	11,82	......	30,40	2.51	2.71	0.93
2. *Elephas meridionalis*, from Durfort (Gard). Reddish-gray, becoming blue-green by calcination. Slight gain of carbonate of lime, little of chlorine, with slight of sand	16,30	......	36,84	0.88	3.29	0.27
3. *Elephas meridionalis.* Tusk from the Saint-Prest (Eure-et-Loire), from the Geologic stage of Falunien	......	......	38,40	2 11	3.42	0.62

Average of the three Pliocene samples:

Phosphoric acid, ...	35.21	
Fluorine, ...	1.83	Ratio, 0.58.
Fluorine calculed for apatite, . .	3.14	

Miocene.	Organic matter.	Ash				Ratio.
		Oxide of iron.	Phosphoric acid.	Fluorine.	Fluorine of apatite.	
1. *Dinotherium.* Tusk from the Orleans sands (*langhien* stage). Dense, dirty-gray, becoming blue-green clouded by ignition. Gain of carbonate of lime, neither chlorine nor sulphate	6.80	1.50	38.07	2.66	3.40	0.78
2. Mastodon tusk from the deposit of Sansan (Department of Gers). Langhien stage. When broken showed white with brown veins, becoming bluish by calcination. Gain of carbonate of lime but no chlorine, no silica	7,50	0.85	36.40	2.59	3.25	0.80
3. Mastodon, tusk very compact, gray chestnut color becoming gray with a light blue tint after calcination	......	0 75	39.80	2.36	3.55	0 66
4. *Rhinoceros brachypus.* Tibia from the calcaire of Simorre (*langhien* stage). Orange color, passing to reddish-brown by calcination. Gain of carbonate of lime, chlorine in normal quantity, a little silica	9.65	......	34.73	2.80	3.10	0.90
5. Gazelle horn from the tortonien deposit of Mont-Leberon (Department of Vaucluse). Yellowish-white, becoming bluish by ignition. Much carbonate of lime, traces of chlorine, no silica..	6.70	1.93	15.54	0.78	1.38	0.57
6. *Hipparion.* Radius from the same deposit as No. 5. Yellowish-white which changes not by calcination. Slight gain of carbonate of lime, traces of chlorine	7.54	0.96	37.90	0.90	3.38	0 27
7. *Hipparion* from Pikermi (Greece). Yellowish-white, persisting after ignition; carbonate of lime abundant	8.54	0.90	34.26	0.93	3.06	0.31

Average of the seven Miocene specimens:

Phosphoric acid, ...	33.81	
Fluorine, ...	1.86	Ratio, 0.61.
Fluorine calculated for apatite, . .	3.02	

Oligocène.	Organic matter.	Ash				Ratio.
		Oxide of iron.	Phosphoric acid.	Fluorine.	Fluorine of apatite.	
1. *Halitherium schinzi* from the tongrien sands of d'Etrechy (Department of Seine-et-Oise). Dense, yellow-orange, becoming reddish-brown by calcination. Carbonate of lime and chlorine in normal quantities, little silica	9.30	4.60	36.65	1.86	3.27	0.57
2. *Halitherium schinzi* from the tongrien deposit of d'Etang-la-ville (Department of Seine-et-Oise). Dense, when fractured shows brilliant dark chestnut, its powder becomes gray and remains the same after calcination. Carbonate of lime in normal quantity, traces of chlorine, little silica.	8.31	2.20	36.70	3.26	3.27	1.00
3. Ruminant. Bone from the deposit of Auvergne. Grayish-white, average density with a slightly blue tint by calcination. Carbonate of lime and chlorine in normal quantities, no silica	7.83	......	38.80	2.46	3.46	0.71
4. Rhinoceros. Bone from the deposit of phosphorites of Quercy. The exterior zone is hard and compact, violet and white mixed; with an interior zone, porous, red, with white crystals of carbonate of lime. The exterior zone only was analyzed. The powder was gray and took a bluish tint by calcination. Carbonate of lime abundant. Traces of chlorine, no silica	5.90	1.80	35.08	0.62	3.12	0.20

Average of the four samples from the Oligocene :

Phosphoric acid, ...	38.81	
Fluorine, ...	2.05	Ratio, 0.59.
Fluorine calculated for apatite, . .	3.46	

Eocene.	Organic matter.	Ash				Ratio.
		Oxide of iron.	Phosphoric acid.	Flourine.	Fluorine of apatite.	
1. *Paloplotherium codiciense.* Pelvic bone from the calcaire of Jumencourt (Department of Aisne). Light, easy to pulverize, brownish, becoming a gray yellowish with bluish tint by ignition. Carbonate of lime abundant, but little chlorine and little silica	13.06	0.70	31.10	2.45	2.77	0.88
2. Crocodile—Lower Eocene. Bone of the head. Dense, black-brown, becoming reddish-brown by ignition. Notable quantity of pyrites of iron, carbonate and sulphate of lime with traces of chlorine	10.30	6.50	30.03	1.40	2.68	0.52
3. *Anoplotherium commune.* Metacarpal from la Debruge (Department of Vaucluse). Dense, fracture showing mat, with a blackish brown, studded with white crystals and brilliants of carbonate of lime. Is easily powdered when it becomes gray-chestnut, and by igninition passes to a gray-white	11.72	0.66	29.09	1.98	2,59	0.76
4. *Palætherium magnum.* Cubitus from the gypsum of Villette (Paris). Porous, fracture shows a yellow color; after ignition the powder becomes greenish-white. A gain of carbonate of lime, a little sulphate with traces of chlorine	8.67	0.80	33.70	2.05	3.01	0.68
5. Turtle. Shell from the gypsum of Paris (the lower stage ligurien). Light, porous, orange color, becoming white by ignition. Gain of carbonate of lime, notable quantity of sulphate, traces of chlorine and no silica	7.80	0.90	27.26	1.64	2.43	0.67

Average of the five specimens from Eocene:

Phosphoric acid,	30.39	
Fluorine,	1.90	Ratio, 0.70.
Fluorine calculated for apatite,	2.71	

Cretaceous.	Organic matter.	Ash				Ratio.
		Oxide of iron.	Phosphoric acid.	Fluorine.	Fluorine of apatite.	
1. *Mosasaurus camperi.* A vertebra from the chalk of Maestricht, Belgium. Porous, a grayish-brown, becoming slightly green by calcination. Carbonate of lime in large quantities, traces of chlorine, no silica......	10.18	2.50	32.73	3.06	2.92	1.05
2. Large turtle from the same locality with the same characters. The colors slightly more reddish..................	8.69	4.10	36.10	3.33	3.22	1.03
3. Reptile *dinosaur* from the superior cretaceous of Ariege. White, dense, becoming green or greenish by calcination. Carbonate of lime in considerable quantity, traces of chlorine, no silica....................................	7.53	0.47	32.70	2.85	2.92	0.98
4. *Iguanodon*—wealdien of Bernissart, Belgium. Black, dense, fragile; giving a powder of light gray, turning slightly yellow, but becoming clear gray with light green tint by ignition. Carbonate of lime in rather large quantity, sulphate of lime in notable quantity, no pyrites, a little silica, traces of chlorine.............	6.47	2.37	32.17	2.62	2.87	0.91
5. Reptile *dinosaur.* Rib from the wealdien stage of Filgate, Southern England. Porous, brownish-gray, becoming chestnut gray by ignition. Carbonate of lime in about normal quantity, traces of chlorine, no silica..	8.80	3.30	38.65	2.76	3.45	0.80
6. Reptile *dinosaur* of the wealdien of Lewes, Southern England. Reddish-chestnut, becoming a dirty gray with a light blue tint by ignition. Carbonate of lime in normal quantity, a little silica, traces of chlorine, absence of sulphate of lime and pyrites....................	9.20	3.18	36.32	2.59	3.18	0.80

Average of the six Cretaceous specimens:

Phosphoric acid,	34.92	
Fluorine,	2.87	Ratio, 0.92.
Fluorine calculated for apatite,	3.11	

Jurassic.	Organic matter.	Ash				Ratio.
		Oxide of iron.	Phosphoric acid.	Fluorine.	Flourine of apatite.	
A. Oolithic.						
1. *Ichthyosaurus.* Vertebra from the kimmeridigian clays of Havre. Dense, black, fracture mat, with much carbonate of lime crystallized, a little sulphate of lime, iron pyrites, a little silica and clay......................	17.25	0.68	6.40	0.56	0.57	0.98
2. *Teleosaurus cadomensis.* Bony escutcheon from the grand oolithic deposit (bathonien) of Caen (Department of Calvados). Dense, brownish-gray, passing to grayish yellow by calcination. Carbonate of lime and sulphate of lime in notable quantities, a little clay, traces of chlorine..	7.30	0.90	34.97	2.31	3.12	0.74
3. *Pholidophorus.* From the lithographic calcaire of Cerin (Department of Yonne). Imprints of fishes. A reddish-yellow, passing by ignition into a rose color, lightly tinted with yellow and green. Carbonate of lime in notable quantity, traces of chlorine, no silica......	11.62	1.05	33.94	1.89	3.03	0.62
B. Lias.						
4. *Ichthyosaurus burgundiæ.* Vertebra from the superior lias of Saint Colombe, (Department of Yonne). Dirty gray, with slightly yellowish, remaining same color after ignition. Lamellar texture due to the abundance of carbonate of lime *spathique*, traces of chlorine, a little pyrites, absence of silica and sulphate of lime......	6.78	2.47	12.93	1.38	1.15	1.20
5. *Ichthyosaurus.* Vertebra from the middle lias of Calvados. Dense, chestnut mixed with white, strewed with crystals of carbonate of lime; breaks and pulverizes easily; it is broken down in the fire and it becomes yellowish-orange with traces of green; much carbonate of lime, a little silica, ferruginous clay of sulphate of lime, no pyrites, chlorine in normal quantity..................	8.85	2.30	11.04	0.96	0.98	0.98
6. *Teleosaurus* of lias. Dense, reddish-brown, becoming yellowish-gray, with bluish portions by ignition; much carbonate of lime, a little silica and clay, absence of sulphate of lime and pyrites of iron, chlorine normal...	13.38	4.65	10.57	0.86	0.94	0.91
7. *Plesiosaurus.* Vertebra of the lower lias of Vievry, near Igornay, Department of Saone-et-Loire. Orange, slightly gray, passing to a blackish-gray by ignition. Fibrous texture, semi-crystalline, by abundance of carbonate of lime, more than the average quantity of chlorine, a little silica..	15.24	2.73	14.79	2.19	1.31	1.67

Average of the seven Jurassic specimens:

Phosphoric acid, ...	17.79	
Fluorine, ...	1.44	Ratio, 0.91.
Fluorine calculated for apatite, . .	1.58	

Triassic.	Organic matter.	Ash				Ratio.
		Oxide of Iron.	Phosphoric acid.	Fluorine.	Fluorine of apatite.	
1. *Simosaurus.* Femur from muschelkalk of Bayreuth in Bavaria. Orange-yellow, becoming greenish-yellow by ignition. Carbonate of lime in considerable quantity; chlorine normal, no silica	11.92	2.41	19.64	1.40	1.75	0.80
2. Reptile from muschelkalk of Moselle. Light brown, becoming gray after ignition. Gain of carbonate of lime, very little magnesia and chlorine, and a little ferruginous clay	16.28	1.75	24.23	2.07	2.16	0.96

Average of the two Triassic specimens:

Phosphoric acid,	21.93	
Fluorine,	1.74	Ratio, 0.89.
Fluorine calculated for apatite,	1.95	

Permo-Carboniferous.	Organic matter.	Ash				Ratio.
		Oxide of Iron.	Phosphoric acid.	Fluorine.	Fluorine of apatite.	
1. *Pleuracanthus frossardi.* Cartilaginous fish from Thelots near Autun (Department of Seine-et-Loire). A hard and black imprint on schist. The detached fragment gives a dark chestnut powder, becoming bluish-gray by ignition. Phosphate of iron, a little carbonate of lime, a little chlorure soluble in water, abundant residue insoluble in the acid	34.55	3.18	22.57	2.26	2.01	1.17
2. *Palaeoniscus.* Ganoide fish from Muse near Autun. Brilliant scales of a brownish-gray, becoming reddish-brown by ignition. Much iron, considerable quantity of chlorine, no carbonate of lime, insoluble residue abundant	22.27	6.70	26.20	1.55	2.33	0.67
3. *Actinodon frossardi.* A reptile labyrinthodonte from Felots near Autun. The same characteristics as No. 1	29.66	2.08	28.35	3.62	2.53	1.43
4. *Haptodus baylei.* Of the same origin and same characteristics	42.52	2.37	28.23	3.15	2.52	1.25
5. *Archegosaurus.* From Lebach near Saarbruck. A black imprint, tender, chestnut powder becoming a brownish-red by ignition. Absence of carbonate of lime and of chlorure, notable quantity of sulphate of lime and a little pyrites of iron. Insoluble residue quite abundant	6.07	6.73	28.37	2.02	2.53	0.80

Average of the five Permian specimens:

Phosphoric acid,	26.74	
Fluorine,	2.54	Ratio, 1.06.
Fluorine calculated for apatite,	2.38	

Devonian.

1. *Asterolepis* Bony plates from the Devonian of Livonia, Russia. Dense, brownish-black, becoming reddish-gray by ignition. Very little carbonate of lime, notable quantity of quartz with traces of chlorine.

Organic matter,	5.20	
Ash: Oxide of iron,	3.02	
Phosphoric acid,.	29.50	
Fluorine,	2.59	Ratio, 0.98.
Fluorine of apatite,	2.63	

Silurian.

The debris of fish extracted from a ferruginous bone breccia of the inferior silurian of Canyon City, Colorado, U. S. A., reported in 1891 by Mons. Albert Gaudry, after his journey to the Rocky Mountains.

Organic matter,	5.67	
Ash: Oxide of iron,	7.47	
Phosphoric acid,	32.63	
Fluorine,	2.72	Ratio, 0.94.
Fluorine of apatite,	2.90	

General observations.—Bones of the same age present great differences in their composition; but one can, nevertheless, conclude from the foregoing series of analyses, in a general fashion, that the fossilization is accompanied by an important increase in the proportion of carbonate of lime, of oxide of iron and fluorine.

For the first two of these elements, the augmentation is too irregular, too usually affected by special influences of the deposit where they were buried, to enable us to indicate with certainty the true fossil state of the bone. We frequently observe, also, a high proportion of carbonate of lime and of oxide of iron in bones which have been buried for a time, either longer or shorter, but which, after all, belong to the modern period.

It is otherwise for the fluorine, and in spite of the great variations in the proportions of this mineral remarked in the bones of the same period belonging to deposits in different localities, it does appear that we may formulate a general law of age based upon the increase in the proportion of fluorine existing in them. This law is shown with greater certainty and clearness in the comparison of the average proportions in the entire number of specimens from each geologic epoch than from the proportions in the individual specimens, and in order to render this more apparent, the table following of geologic epochs shows the average results obtained from the bones of each one of these periods. The first column gives the average proportion (as above calculated) of fluorine to that of an apatite containing the same quantity of phosphoric acid. The second column gives the average ratios of the weight of phosphoric acid to the weight of fluorine.

Geologic Periods.	The ratio between the quantity of fluorine in the bone, to that of apatite.		The ratio of the weight of phosphoric acid in the bone to that of fluorine.	
Modern	0.058	0.058	193.1	193.1
Quaternary	0.36	0.360	31.3	31.30
Tertiary				
pliocene	0.58	0.620	19.2	18.15
miocene	0.61		18.3	
oligocene	0.59		18.9	
eocene	0.70		16.0	
Secondary.				
cretaceous	0.92	0.907	12.2	12.40
jurassic	0.91		12.3	
triassic	0.89		12.6	
Primary.				
permo-carboniferous	1.06	0.993	10.5	11.30
devonian	0.98		11.4	
silurian	0.94		12.0	
Apatite normal	1.00	1.000	11.21	11.21

The averages set forth in the figures of this table are not to be taken as of absolute, but only as of relative, value. The only ones which can be considered definite are those relative to apatite on the one side and to the modern bones on the other. For the fossil bones, the average not only varied with the choice and number of the specimens analyzed, but the specimens taken for analysis were varied as much as possible and in sufficient number as to leave no doubt as to the correctness of the final result. There is a progressive increase in the quantity of fluorine as compared with the quantity of phosphoric acid, between the bones of modern times and those of quaternary times; and that the latter contain, on the average, six or seven times more than do the bones from the tertiary, secondary or primary epochs.

The tertiary bones contain, on the average, eleven times more fluorine than the modern bones, and this augmentation appears gradually from one geological period to another.

The bones belonging to the secondary epoch have a proportion of fluorine sixteen times more, and those of the primary, eighteen times more than the modern bones.

The bones of the most ancient epochs have almost exactly the same proportion of crystallized apatite; the secondary bones are not far behind, but the loss becomes sensible in the tertiary bones, and more so in the quaternary bones. The contrast is still more striking in modern or recent bones, where the fluorine is found in a minimum proportion.

Causes of the increase of Fluorine in Fossil Bones.—What can be the cause of this progressive enrichment of fossil bones in fluorine? How can one explain that this increase has for a general limit the proportion of fluorine in apatite, although this limit is sometimes exceeded? It seems proper to say "increase of proportion of fluorine," as we could not admit for an instant that the bones of ancient animals contained during their life the proportions of fluorine which we now find in them. Even if this were not opposed to known physiological law, it would still become necessary to reject the theory because of the considerable difference observed in the composition of bones coming from the same species, whether from the same or from different epochs. The question arises—what could have been the vehicle of the fluorine? We can only think of gas or liquid, i. e., of something belonging to atmosphere or water. But as we have no knowledge of any chemical condition of fluorine under which it could be carried in a gaseous state in a humid atmosphere in the sedimentary strata, we are obliged to conclude that it penetrated into these strata under the form of an aqueous solution. It is, therefore, to infiltration of water, that has, during the lapse of time, come in contact with these fossil bones, that we must attribute this increase of fluorine, as well as other chemical changes, like the fixation of oxide of iron, the fixation and more rarely the disappearance of carbonate of lime, the solution of phosphate, etc. According to all appearance, the infiltrating water carries traces of fluorine in solution, and these traces have been fixed progressively on the phosphate of lime, by virtue of some sort of affinity which we may suspect, remarking that all crystallized phosphates of lime contain fluorine (or chlorine) in a constant quantity. But there are other proofs—the affinity of the phosphate of lime for fluoride or for chloride of calcium at a high temperature has been demonstrated by the experiments made in connection with the synthesis of apatite, which synthesis was made first by Mons. D'Aubrée (by means of lime and chloride of phosphorus), then by Forschammer (by phosphate of lime and chloride of sodium), then by H. Sainte Claire Deville and Caron (by phosphate of lime and chloride of calcium).

Experiments have been made to determine whether the same affinity was sensible in the cold and by the wet way; and if the phosphate of lime in modern bones could fix the fluoride of calcium in analogous conditions with those in which the fossil bones must have been (save and except the lapse of time and the degree of concentration of the liquids).

Experiment No. 1.—A bone of a manatee (in fragments) was placed in 200 cubic centimetres of a solution of alkaline fluoride diluted to the 50th part, containing 2 grams of carbonate of ammonia. At intervals of time, longer or shorter, fragments of this bone were taken out, carefully washed and dried and subjected to analysis for fluorine. The proportion of bone in the fluorine was originally $\frac{31}{100}$ of one per cent. After remaining fifteen days in this solution, had increased to 1.70 per cent. After remaining a month in the liquid, it contained 2.81 per cent, and after five months, 7.74 per cent. The proportion, however, of phosphoric acid had, on the contrary, been reduced from 38.93 to 35.06. There had been a formation of fluoride of calcium at the expense of the original phosphate of lime and carbonate of lime, and a mixture which contained more fluorine than apatite had been formed; for the latter would have contained only 3.13 of fluorine instead of 4.74.

Experiments 2 and 3.—Two analogous experiments were made with solutions of chloride in which were placed the fragments of the bones of the manatee containing at the beginning $\frac{16}{100}$ of one per cent of chlorine in the form of an insoluble compound. After remaining for three months in a solution of one tenth of chloride of sodium, we showed $\frac{16}{100}$ of one per cent (0.16) of insoluble chlorine. After three months in solution of one-twentieth of chloride of sodium and one-twentieth of chloride of calcium, the bones contained 0.24 per cent of chlorine in an insoluble state. Therefore, there had not been any fixation of chlorine by the action of chloride of sodium alone on the phosphate of lime, but it was by the action of chloride of calcium; the proportion of chlorophosphate formed was otherwise much less than that of fluophosphate produced by a solution, even very feeble, of an alkaline-fluoride. We can conclude that the affinity of phosphate of lime is much greater for the fluoride than for the chloride.

Experiment No. 4.—In other experiments, instead of using an alkaline-fluoride easily soluble in water, there was employed fluorspar in fine powder, to which was added distilled water, with a little carbonate of ammonia, a salt which frequently forms near, on, or in the bone by reason of the decomposition of organic matter, and which can aid in the solution of a small quantity of fluoride of calcium.

The fragments of the bones of the manatee were placed in an uncovered vessel with sand, with 200 cubic centimetres of distilled water and 2 grams of carbonate of ammonia, and it was noticed that the proportion of fluorine which, at the beginning, was 0.31 per cent, became 0.35 at the end of the month and 0.43 at the end of three months. While the bones were thus immersed, the solution was frequently shaken and distilled water added to replace loss by evaporation. There was, under these conditions, a notable increase in the bones, of fluoride of calcium, despite the slight solubility of the fluorspar employed as a re-agent. We then have the right to suppose that the continuous action during an indefinite time could produce a fluoration much more advanced than that shown in the experiment. The analyses or attempts did not succeed the same in closed vases where the bones were in the presence of the powder of fluorspar and of carbonate of ammonia of 2 grams, whether with seltzer water only, or with the seltzer water and sand. After three months of trial, one of the bones showed 0.32 and the other 0.31 of fluorine.

The experiment was also made of the action of a copper-zinc couple in the mixture; but at the end of four months this contained still 0.30 per cent of fluorine, about the same as at the begininng. From these negative results we may make certain inductions which may be of utility in explaining the phenomena.

There was realized in experiments 1 and 4 the gradual fixation of fluoride of calcium on the phosphate of lime of the bones, whether using fluoride of calcium in powder (of which a small proportion was dissolved in the water containing carbonate of ammonia), or whether in producing action upon the bones by a small quantity of alkaline fluoride in solution. The alkaline fluoride can act directly upon the phosphate of lime in giving birth to fluoride of calcium and to a soluble alkaline phosphate, from which results a diminution of the proportion of the insoluble residue of phosphoric acid; or it can produce action of the alkaline fluoride on the carbonate of lime which is found mixed with phosphate in the bone and which causes the formation of fluoride of calcium.

In cases where the fluoration takes place under the sole influence of fluoride of calcium, it ought to have for its extreme limit, the proportion which we observe in apatite—that is, about one part of fluorine to 11 parts of phosphoric acid. But if the alkaline fluoride intervenes, the fluoration can go farther and reach a proportion much higher than that of apatite. This was shown in Experiment No. 1, and it has been observed in fossil bones and in phosphates of organic origin.

Among the preceding analyses to be especially mentioned are those of three bones from the Permian of Autun (*Pleuracanthus, Actinodon* and *Haptodus*) those of two bones from the Lias of Igornay and of Saint Colombe (*Plesiosaurus* and *Ichthyosaurus*), the two bones from chalk of Maestricht (*Mosasaurus* and large turtle). The same effect was remarked by M. Phipson before the Acadamie des Sciences, Oct. 3, 1892. It is, therefore, not rare to meet with proportions of fluorine greater than that of apatite for the same quantity of phosphorus.

In some of the experiments heretofore given the proportion of fluorine, compared to that of apatite, which is taken for the unit, was increased from 1.03 to 1.67. The excess of fluoride of calcium can be attributed to the action of the alkaline fluoride in the solution, alone or mixed with fluoride of calcium, while the latter has perhaps alone produced the metamorphoses of the bones in which the proportion of fluorine does not exceed or perhaps has not even attained that of apatite.

In every point of view, in order to explain the fluoration of bone, there is admitted the existence of fluorine in solution in the waters which come in contact with these bones; at least this is the most plausible supposition, for, on the one hand, the fluorides and in particular the fluoride of calcium is sufficiently prevalent, not only in the crystalline rocks, notably in the masses of granite and granulite, but also in a certain number of sedimentary rocks, for example, coal-bearing strata in arkoses of Burgundy, in the *muschelkalk*, even in the *calcaire* of Paris, which appear to sufficiently indicate that waters charged with fluoride of calcium can circulate throughout these deposits; and on the other part, the fluoride of calcium not being completely insoluble, the infiltrated water, either more or less charged with carbonic acid, and with alkaline salts and salts of ammonia, could take it up from the rocks through which the water traversed and which are more or less impregnated with fluorine.

Many analyses of various waters reveal the existence of fluorides in solution even though in minute quantities. Nicklès found it in the waters of the Seine at Paris, of the Somme at

Ameins, of the Rhine at Strasbourg, and of the mineral waters of Plombières, Contrexville, Antogast, Chatenois, Vichy (Compte Rendus, 1857, Vol. I, page 783; Vol. II, pages 250 and 331). Also by Charles Mène in the waters of the Rhone, Saone, Loire; by Rose in the well-waters of the neighborhood of Berlin (Compte Rendus, 1860, Vol. I, page 731); in the waters of Plombières by Jutier and Lefort (9 or 10 millegrams per litre); Carlsbad by Berzelius (3 mg, 2); Kreusbrunnen by Berzelius (traces); Kissingen and Aix-la-Chapelle by Leibig (traces); d'Orezza by Poggiale, the latter ones cited in the Dictionaire de Chimie by Wurtz, Vol. II, page 1206.

Clemm and Forchhammer recognized in the deposits formed by the evaporation of sea water, phosphate of lime accompanied by carbonate and fluoride (Daubrée, Gisements de chaux phosphatée, Annales de Mines, 1868, page 81.)

The existence of fluorides has been also discovered in different substances, both animal and vegetable, as blood, milk, urine, yellow of the egg (Nicklès, Compte Rendus, 1857, Vol. II, page 331; Tamman, Zeitschrift f. physiolog. Chimie, 1888, page 322).

And finally, this substance is much more extensively diffused than has been generally believed. There is, therefore, nothing astonishing that the infiltrated waters which come in contact with animal bones should contain in small quantities the fluorides in solution, and should produce, in the course of a long period of time, a sensible modification in the composition of those bones; but which must have been affected with extreme slowness because of the very feeble proportion of fluorides in solution. Ordinarily the traces are so minute that it is extremely difficult to recognize them by analysis, and it must have taken a great number of centuries for the variation in the proportion of fluorine to become appreciable. The other changes in the nature of bones are often much more rapid and more irregular. An augmentation of several hundredths in the proportion of oxide of iron can be produced in a short interval of time. It is the same with a notable variation in the proportions of phosphate and carbonate of lime; while, as for the silica, sulphate of lime, pyrites of iron, they are encountered only in an accidental manner. The different modifications in the chemical composition of bones, depend essentially upon the nature of the filtrating water and by consequence with that of the strata which they percolate.

It is the same as to the proportion of organic matters which diminish with time, but in a very irregular fashion according as the earth is more or less permeable. There is even to be found, sometimes, considerable organic matter in bones of great antiquity. The differences are too great between one deposit and another for us to be able in general to draw from the presence or the proportion of these elements, any induction as to the length of time the bones have remained in the earth.

The fixation of fluorine upon the phosphate of the bones is subordinate in a certain measure to the conditions of the deposits and surrounding earth. The local circumstances have probably a much less influence because of the slowness of the phenomena. In any case, the series of analyses which are here given, show clearly that the proportion of fluorine increases at a perceptible rate during the later geological periods, and that it can furnish in consequence better than the other elements a characteristic indication of the antiquity of the bone.

The following conclusions seem to be justifiable. In the different deposits of the primary and secondary geologic epochs, the relative proportions of fluorine and of phosphoric acid are, upon the average, about the same as in crystallized apatite. In the tertiary and quarternary deposits there is a progressive and marked decrease in the proportion of fluorine, but this proportion remains during these epochs much higher than in modern times. It will, perhaps, be possible to use this means to fix the veritable age of certain human bones which have been found in the neighborhood of quaternary animals, but the deposits of which may have been disturbed and the bones mixed. We cannot at present, from these experiments, establish this as a general method for the determination, accurate or absolute, of the degree of antiquity of human bones in all deposits, for the different chemical compositions of the deposits may produce differences in the composition of the bones which will neutralize all our efforts in this direction.

The incident at Billancourt affords an excellent illustration. Mons. Rivière, of Paris, sent to Mons. Carnot at the Ecole des Mines, two fragments of animal bones and one human tibia to be submitted to analysis (Bull. Soc. Anthrop., Paris: No. 6, 15 July, 1893, Vol. 4, 4th Serie, page 309). The animal bones were white, friable and quite dense; the human tibia was brownish-yellow, light and soft enough to crush under reasonable pressure. The ignition showed the following: In the animal bones, the organic matter was from 12.93 to 12.69; with the human tibia it was 19.65, and, therefore, the decomposition of the latter was much less than that of the first. The ash of the animal bone was a greenish-white; of the human, a bluish-gray attributable probably to phosphate of iron. The determination of peroxide of iron gave in effect 0.19 to 0.21 for the animal bone, and 3.06 for the human tibia. This difference gives a presumption against the age of the two sets of bones being the same. The proportions of carbonate of lime differed slightly; for carbonic acid, the animal bones gave from 6.06 to 4.75, while it was 6.15 in the human tibia. The determination of the phosphoric acid and fluorine were as follows:

	Fossil animal. Long bones.	Fossil animal. Scapula.	Modern? Human Tibia.
Phosphoric acid	34,30	35,67	28,72
Fluorine	1,43	1,84	0,17

The phosphoric acid, then, had diminished more in the human bones than in the animal as though the latter had been more ancient. But the relationship between the phosphoric acid and the fluorine is found as follows in the three cases:

	23,9	19,4	168,9

As has been established in the table on page 447, the relation between the weight of the phosphoric acid and the weight of fluorine and water was in the neighborhood of 193 in modern bones, while it became reduced to 31 in the average of quaternary bones, and 19 for their average in bones of the pliocene period. Therefore, the animal bones found in the sands of Billancourt present a relative proportion of fluorine intermediate between the average of the quaternary bones and those of the pliocene, that is to say, for the one was 23.9, for the other, 19.4.

On the contrary, for the human tibia submitted to analysis, the relation is raised to 168.9 and it is, therefore, 8 times greater than in the animal bones, and is only slightly lower than that of the modern bones. We can, therefore, conclude that the human bone belongs to an age much more recent than those of the animal, and that if it was really in the ancient gravels of the Seine in the neighborhood of the found bones of the quaternary animal, it was only by reason of a natural change of position or else the result of accident.

It is believed that this new method of control may prove to be of utility in determining the problems relative to the antiquity of man. It often happens that in the excavations made in prehistoric stations, one encounters human bones associated with animal bones, whether in alluvial deposits, caverns or rock-shelters. If the man and the animal in these deposits were contemporaneous, their bones, having been exposed to the same influence and submitted to the same transformation, ought to have approximately the same proportion of phosphoric acid and fluorine. But if the human bones are of an age much more recent than those of the animal and have been introduced either by accident or fraud, we can, perhaps, find the proof by this chemical analysis and be able to detect the error by the difference in the relative proportions between their phosphoric acid and fluorine.

(*To be Continued.*)